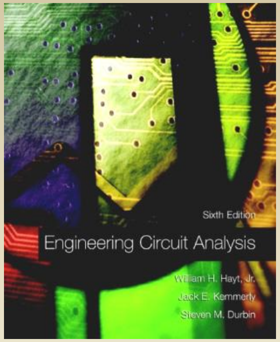


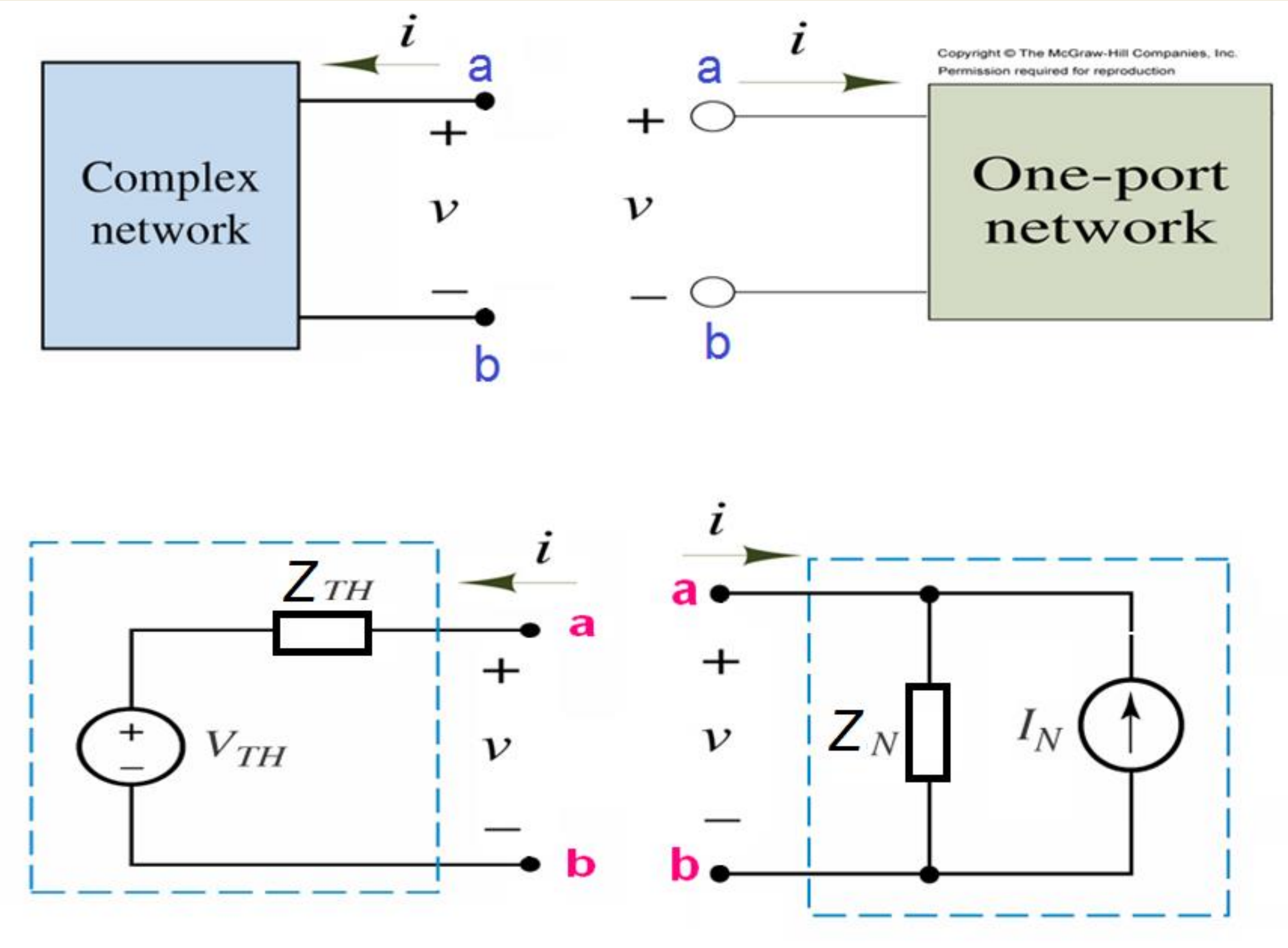
Chapter 17 Two-Port Networks

User Note:

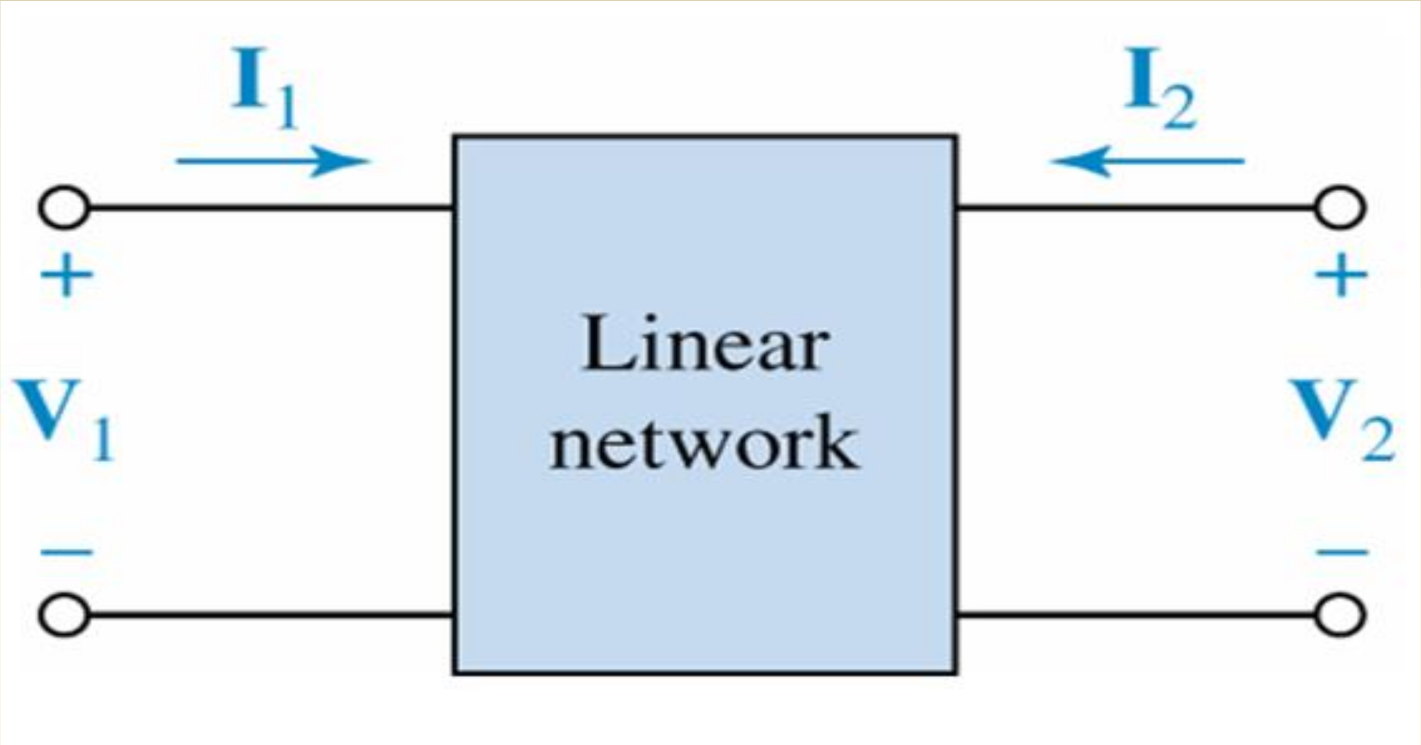
Run **View Show** under the **Slide Show** menu to enable slide selection.

W.H. Hayt, Jr., J.E. Kemmerly, S.M. Durbin, Engineering Circuit Analysis, Sixth Edition.

A one-port network:
Equivalente Thevenin y/o Eq. Norton



A two port network.



A general two-port with terminal voltages and currents specified. The two-port is composed of linear elements, possibly including dependent sources, but not containing any independent sources.

W.H. Hayt, Jr., J.E. Kemmerly, S.M. Durbin, Engineering Circuit Analysis, Sixth Edition.

Ecuaciones que describen una red bipuerto:

$$Q_1 = K_{11}P_1 + K_{12}P_2$$

$$Q_2 = K_{21}P_1 + K_{22}P_2$$

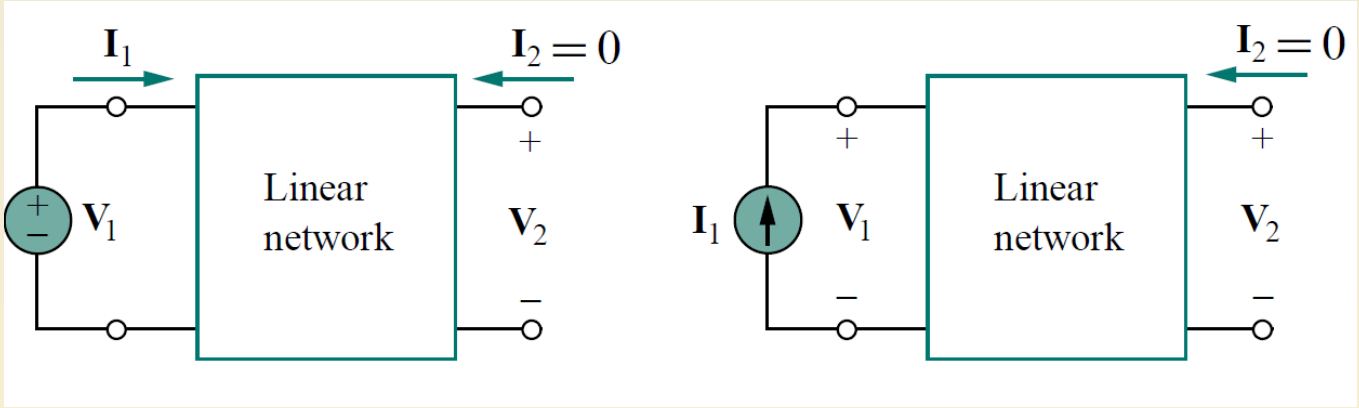
$$\Rightarrow \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix}$$

Caso	Q_1	Q_2	P_1	P_2	Tipo de Parámetros
1	V_1	V_2	I_1	I_2	**Z**: Impedancia o ckto abierto (OC)
2	I_1	I_2	V_1	V_2	**Y**: Admitancia o corto ckto (SC)
3	I_1	V_2	V_1	I_2	**q**: Híbridos inversos
4	V_1	I_2	I_1	V_2	**h**: Híbridos
5	V_1	I_1	V_2	I_2	**t**: ABCD o Transmisión
6	V_2	I_2	V_1	I_1	***T´***: *$\mathscr{ABCD}$ o Transmisión inversos*

Caso 1: Parámetros "**Z**" o de circuito abierto:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \Rightarrow \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

haciendo $I_2 = 0$: (puerta$_2$ en ckto abierto)



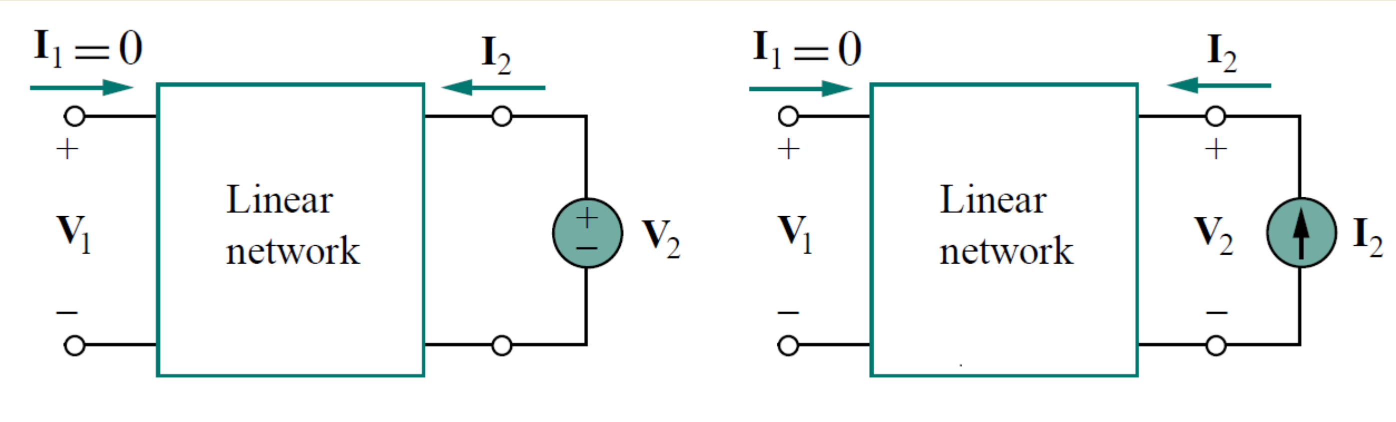
$$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} \Rightarrow Z_{in} \text{ puerta}_1 \text{ con puerta}_2 \text{ abierta}$$

$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0} \Rightarrow \text{trans\_impedancia}_{21} \text{ a puerta}_2 \text{ abierta}$$

Caso 1: Parámetros "Z" o de circuito abierto:

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

haciendo $I_1 = 0$: (puerta$_1$ en ckto abierto)



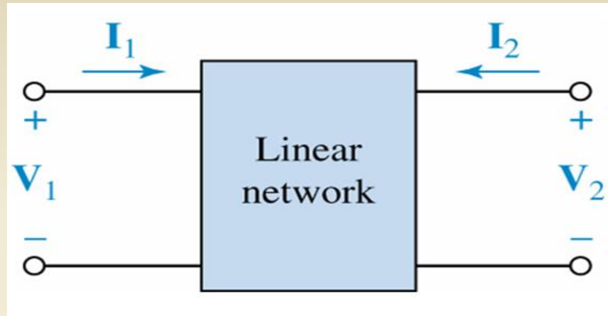
$$Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0} \Rightarrow \text{trans\_impedancia}_{12} \text{ a puerta}_1 \text{ en ckto abierto}$$

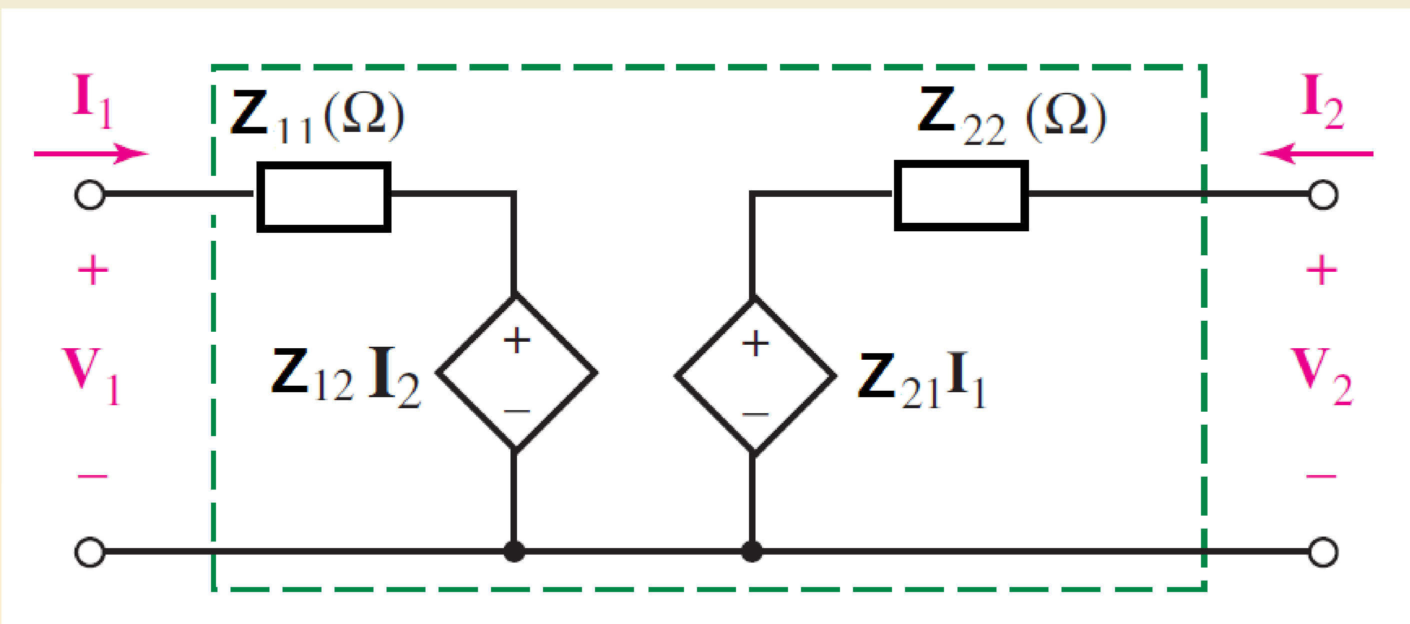
$$Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0} \Rightarrow Z_{in} \text{ puerta}_2 \text{ con puerta}_1 \text{ abierta}$$

Caso 1: Parámetros "**Z**" o circuito abierto:

Red bipuerto equivalente (≈ doble thevenin)

$V_1 = Z_{11}\cancel{I_1} + Z_{12}\cancel{I_2}$

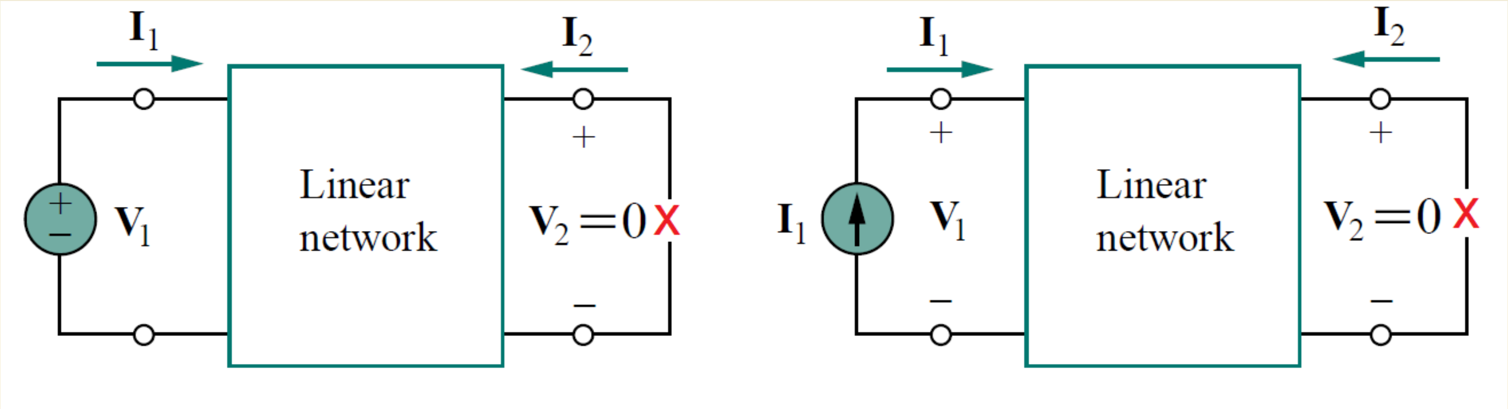




Caso 2: Parámetros "**Y**" o de corto circuito:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

haciendo $V_2 = 0$: (puerta$_2$ en corto ckto)



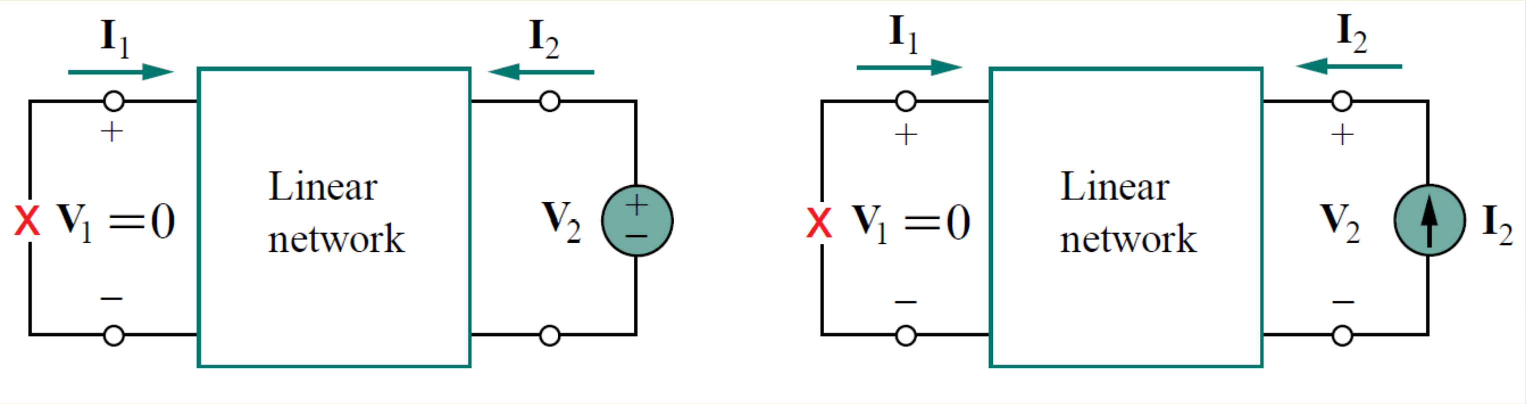
$$Y_{11} = \left. \frac{I_1}{V_1} \right|_{V_2=0} \Rightarrow Y_{in} \text{ puerta}_1 \text{ con puerta}_2 \text{ en corto ckto.}$$

$$Y_{21} = \left. \frac{I_2}{V_1} \right|_{V_2=0} \Rightarrow \text{trans\_admitancia}_{21} \text{ a puerta}_2 \text{ en corto}$$

Caso 2: Parámetros "**Y**" o de corto circuito:

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

haciendo $V_1 = 0$: (puerta$_1$ en corto ckto)

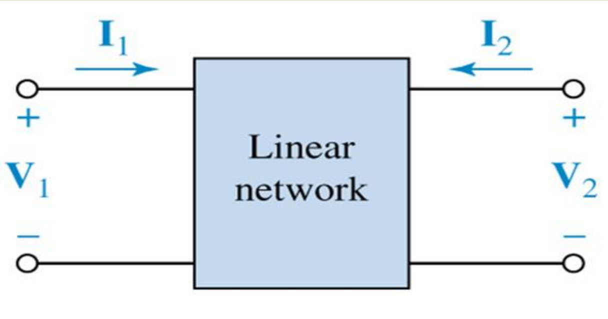


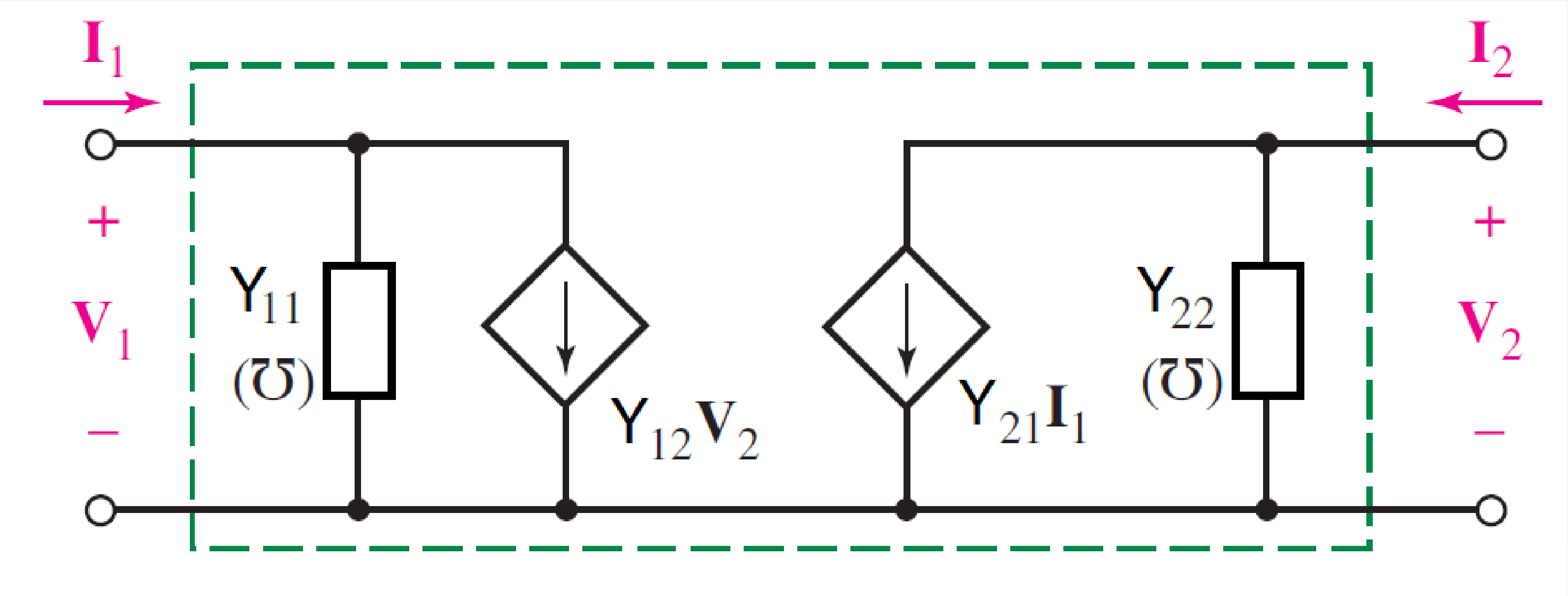
$$Y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0} \Rightarrow \text{trans\_admitancia}_{12} \text{ a puerta}_1 \text{ en corto ckto}$$

$$Y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0} \Rightarrow Y_{in} \text{ puerta}_2 \text{ con puerta}_1 \text{ en corto ckto.}$$

Caso 2: Parámetros "**Y**" o corto ckto:

Red bipuerto equivalente (≈ doble norton)

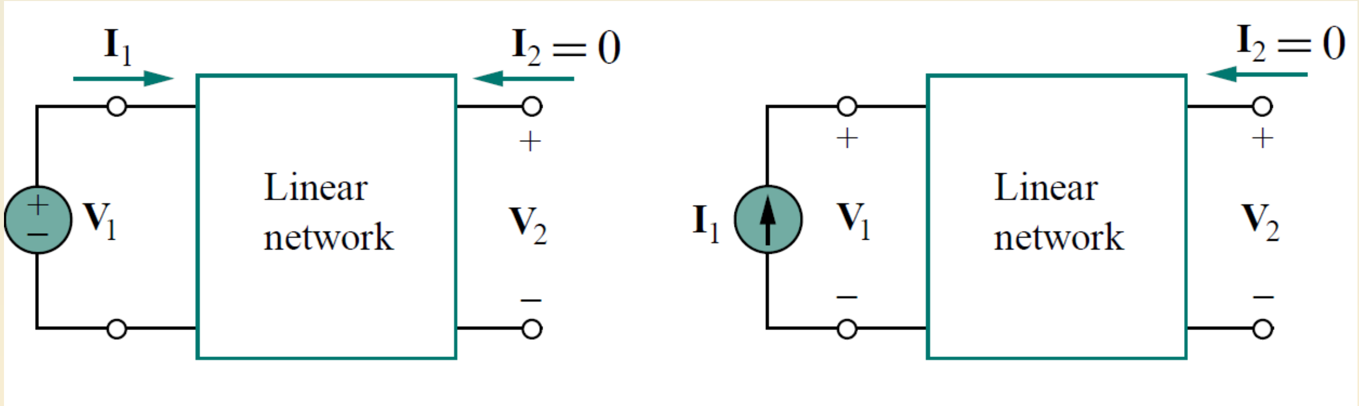




Caso 3: Parámetros "**q**" o híbridos inversos:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \Rightarrow \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} \\ q_{21} & q_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

haciendo $I_2 = 0$: (puerta$_2$ en ckto abierto)



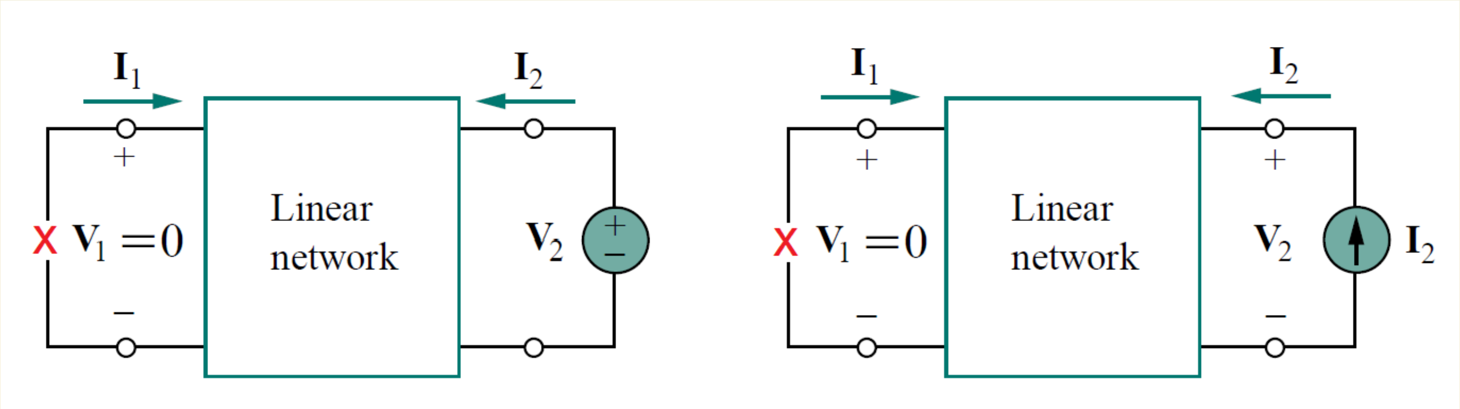
$$q_{11} = \left.\frac{I_1}{V_1}\right|_{I_2=0} \Rightarrow Y_{in} \text{ puerta}_1 \text{ con puerta}_2 \text{ abierta}$$

$$q_{21} = \left.\frac{V_2}{V_1}\right|_{I_2=0} \Rightarrow \text{gain tensión a puerta}_2 \text{ abierta}$$

Caso 3: Parámetros "**q**" o híbridos inversos:

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} \\ q_{21} & q_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

haciendo $V_1 = 0$: (puerta$_1$ en corto ckto)

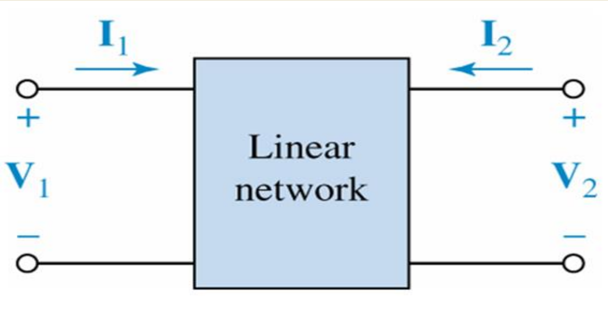


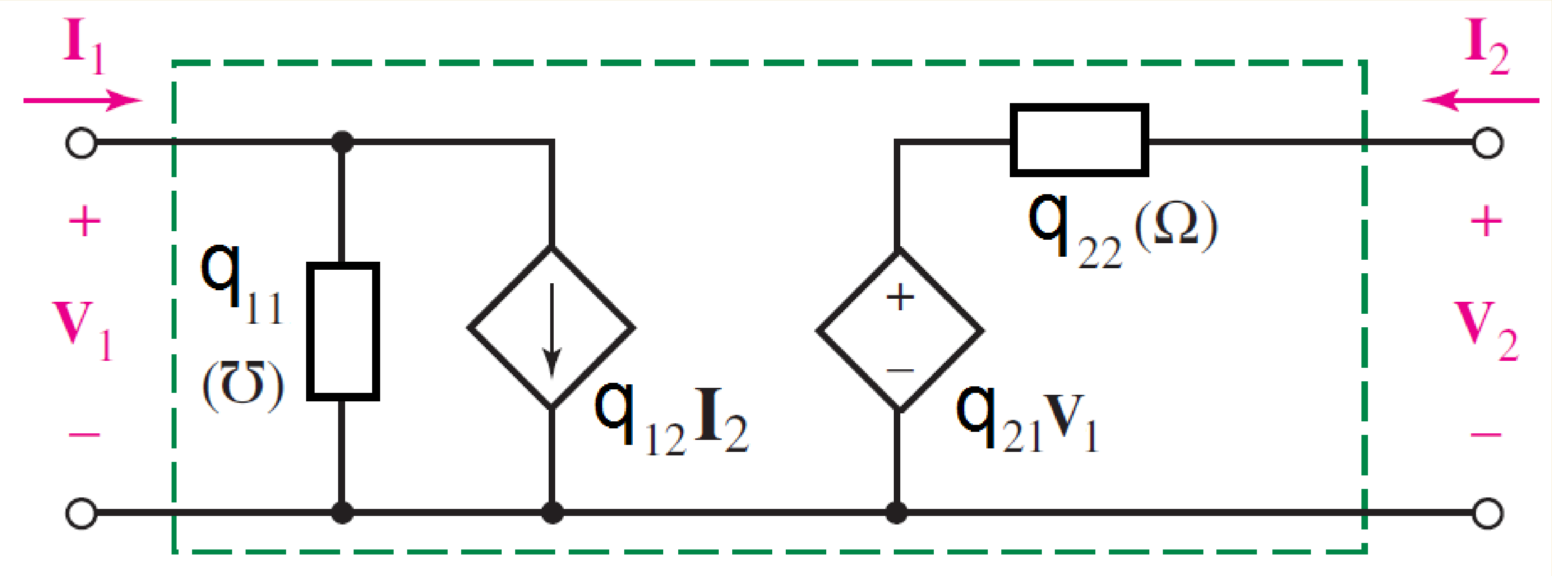
$$q_{12} = \left.\frac{I_1}{I_2}\right|_{V_1=0}$$ $\Rightarrow$ gain inversa de corriente a puerta$_1$ en corto ckto

$$q_{22} = \left.\frac{V_2}{I_2}\right|_{V_1=0}$$ $\Rightarrow Z_{in}$ puerta$_2$ con puerta$_1$ en corto ckto

Caso 3: Parámetros "**q**" o híbridos inversos:

Red bipuerto equivalente (≈ norton+thevenin)

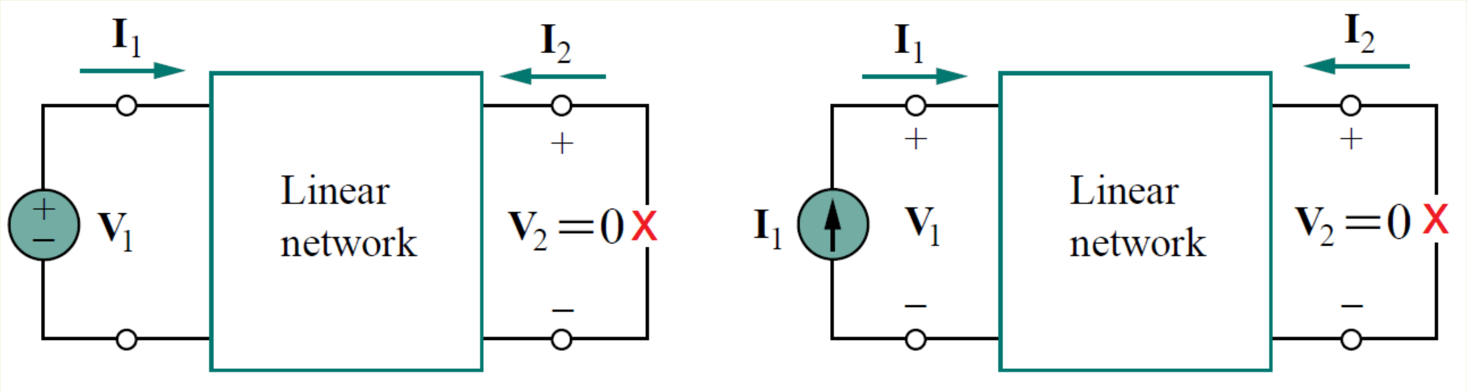




Caso 4: Parámetros "h" o híbridos:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \Rightarrow \begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

haciendo $V_2 = 0$: (puerta$_2$ en corto ckto)



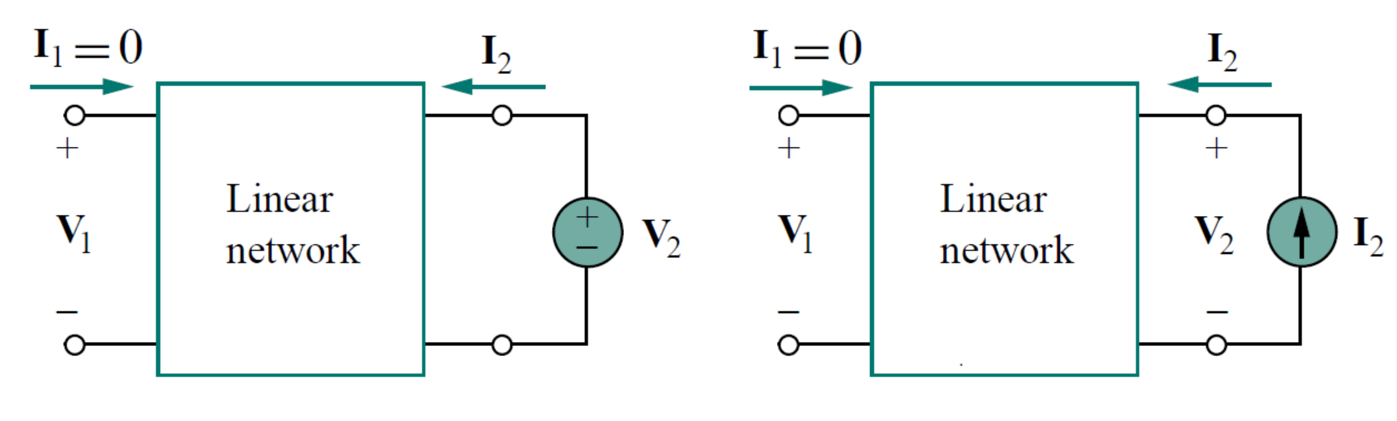
$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0} \Rightarrow Z_{in} \text{ puerta}_1 \text{ con puerta}_2 \text{ en corto ckto}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0} \Rightarrow \text{gain de corriente a puerta}_2 \text{ en corto ckto}$$

Caso 4: Parámetros "**h**" o híbridos:

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

haciendo $I_1 = 0$: (puerta$_1$ en ckto abierto)

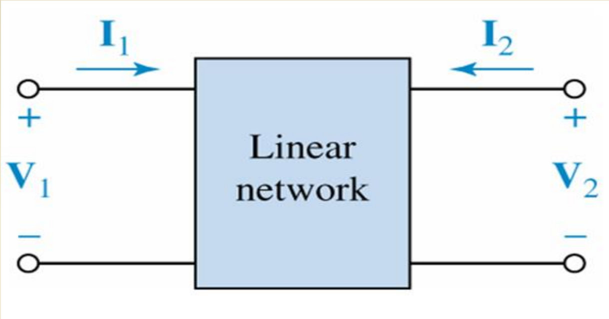


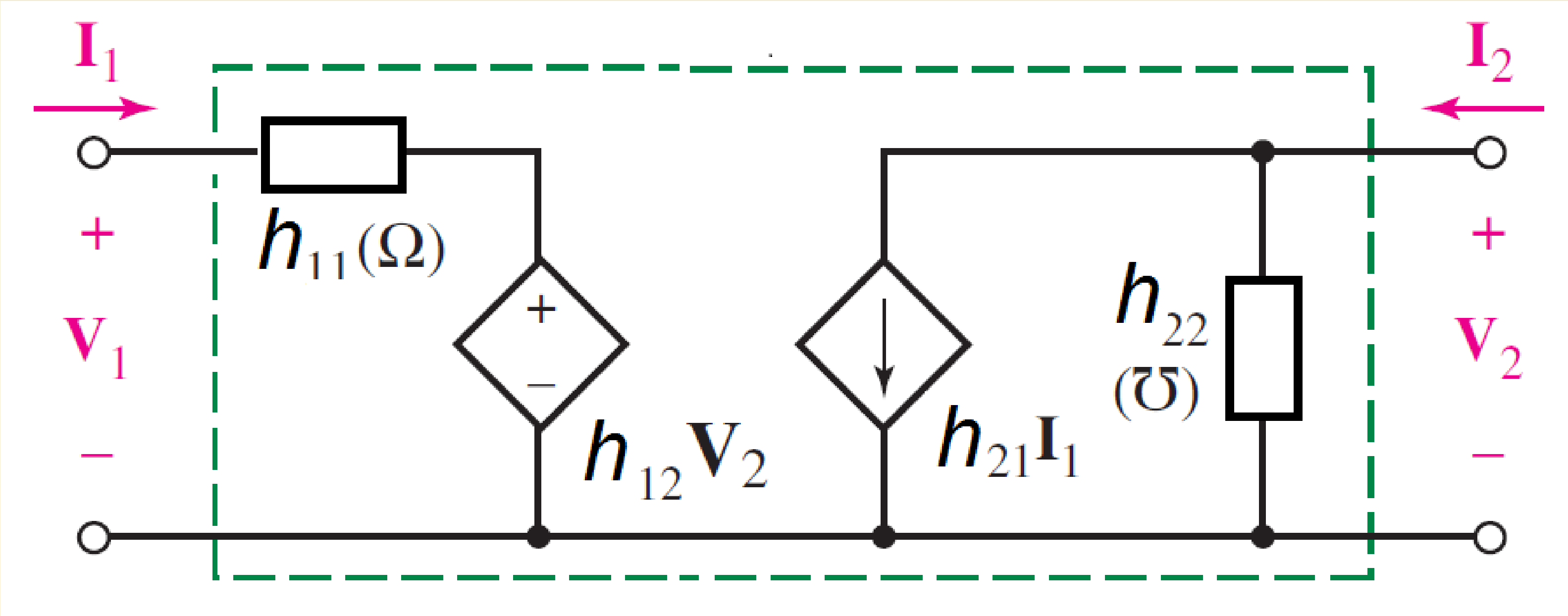
$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0} \Rightarrow \text{gain inversa de tensión a puerta}_1 \text{ abierta}$$

$$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0} \Rightarrow Z_{in} \text{ puerta}_2 \text{ con puerta}_1 \text{ abierta}$$

Caso 4: Parámetros “**h**” o híbridos:

Red bipuerto equivalente (≈ thevenin+norton)





Caso 5: Parámetros "**t**" o "ABCD" o transmisión:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \Rightarrow \begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} \mathrm{A} & \mathrm{B} \\ \mathrm{C} & \mathrm{D} \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

haciendo $I_2 = 0 :$ (puerta$_2$ abierta)

$$t_{11} = \left.\frac{V_1}{V_2}\right|_{I_2=0} = \mathrm{A} \Rightarrow \text{gain inversa de tension con puerta}_2 \text{ abierta}$$

$$t_{21} = \left.\frac{I_1}{V_2}\right|_{I_2=0} = \mathrm{C} \Rightarrow \text{trans\_admitancia}_{21} \text{ a puerta}_2 \text{ abierta}$$

haciendo $V_2 = 0 :$ (puerta$_2$ en corto ckto)

$$t_{12} = \left.\frac{V_1}{I_2}\right|_{V_2=0} = \mathrm{B} \Rightarrow \text{trans\_impedancia}_{12} \text{ con puerta}_2 \text{ en corto ckto}$$

$$t_{22} = \left.\frac{I_1}{I_2}\right|_{V_2=0} = \mathrm{D} \Rightarrow \text{gain inversa de corriente con puerta}_2 \text{ en corto ckto}$$

Caso 6: Parámetros "T" o "$\mathcal{ABCD}$" o transmisión inversos:

$$\begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \end{bmatrix} \Rightarrow \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} V_1 \\ I_1 \end{bmatrix}$$

haciendo $I_1 = 0:$ (puerta$_1$ en ckto abierto)

$$T_{11} = \left.\frac{V_2}{V_1}\right|_{I_1=0} = a \Rightarrow \text{gain de tension con puerta}_1 \text{ abierta}$$

$$T_{21} = \left.\frac{I_2}{V_1}\right|_{I_1=0} = c \Rightarrow \text{trans\_admitancia}_{21} \text{ a puerta}_1 \text{ abierta}$$

haciendo $V_1 = 0:$ (puerta$_1$ en corto ckto)

$$T_{12} = \left.\frac{V_2}{I_1}\right|_{V_1=0} = b \Rightarrow \text{transimpedancia}_{12} \text{ a puerta}_1 \text{ en corto ckto}$$

$$T_{22} = \left.\frac{I_2}{I_1}\right|_{V_1=0} = d \Rightarrow \text{gain corriente con puerta}_1 \text{ en corto ckto}$$

TABLE 18.1 Conversion of two-port parameters.

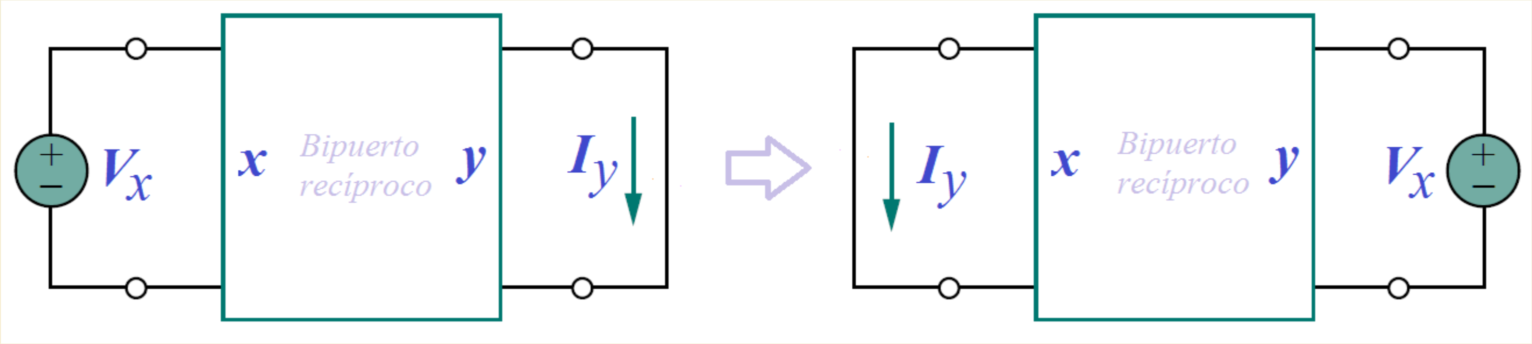
	z		y		h		g		T		t	
z	z_{11}	z_{12}	$\frac{y_{22}}{\Delta_y}$	$-\frac{y_{12}}{\Delta_y}$	$\frac{\Delta_h}{h_{22}}$	$\frac{h_{12}}{h_{22}}$	$\frac{1}{g_{11}}$	$-\frac{g_{12}}{g_{11}}$	$\frac{A}{C}$	$\frac{\Delta_T}{C}$	$\frac{d}{c}$	$\frac{1}{c}$
	z_{21}	z_{22}	$-\frac{y_{21}}{\Delta_y}$	$\frac{y_{11}}{\Delta_y}$	$-\frac{h_{21}}{h_{22}}$	$\frac{1}{h_{22}}$	$\frac{g_{21}}{g_{11}}$	$\frac{\Delta_g}{g_{11}}$	$\frac{1}{C}$	$\frac{D}{C}$	$\frac{\Delta_t}{c}$	$\frac{a}{c}$
y	$\frac{z_{22}}{\Delta_z}$	$-\frac{z_{12}}{\Delta_z}$	y_{11}	y_{12}	$\frac{1}{h_{11}}$	$-\frac{h_{12}}{h_{11}}$	$\frac{\Delta_g}{g_{22}}$	$\frac{g_{12}}{g_{22}}$	$\frac{D}{B}$	$-\frac{\Delta_T}{B}$	$\frac{a}{b}$	$-\frac{1}{b}$
	$-\frac{z_{21}}{\Delta_z}$	$\frac{z_{11}}{\Delta_z}$	y_{21}	y_{22}	$\frac{h_{21}}{h_{11}}$	$\frac{\Delta_h}{h_{11}}$	$-\frac{g_{21}}{g_{22}}$	$\frac{1}{g_{22}}$	$-\frac{1}{B}$	$\frac{A}{B}$	$-\frac{\Delta_t}{b}$	$\frac{d}{b}$
h	$\frac{\Delta_z}{z_{22}}$	$\frac{z_{12}}{z_{22}}$	$\frac{1}{y_{11}}$	$-\frac{y_{12}}{y_{11}}$	h_{11}	h_{12}	$\frac{g_{22}}{\Delta_g}$	$-\frac{g_{12}}{\Delta_g}$	$\frac{B}{D}$	$\frac{\Delta_T}{D}$	$\frac{b}{a}$	$\frac{1}{a}$
	$-\frac{z_{21}}{z_{22}}$	$\frac{1}{z_{22}}$	$\frac{y_{21}}{y_{11}}$	$\frac{\Delta_y}{y_{11}}$	h_{21}	h_{22}	$-\frac{g_{21}}{\Delta_g}$	$\frac{g_{11}}{\Delta_g}$	$-\frac{1}{D}$	$\frac{C}{D}$	$\frac{\Delta_t}{a}$	$\frac{c}{a}$
g	$\frac{1}{z_{11}}$	$-\frac{z_{12}}{z_{11}}$	$\frac{\Delta_y}{y_{22}}$	$\frac{y_{12}}{y_{22}}$	$\frac{h_{22}}{\Delta_h}$	$-\frac{h_{12}}{\Delta_h}$	g_{11}	g_{12}	$\frac{C}{A}$	$-\frac{\Delta_T}{A}$	$\frac{c}{d}$	$-\frac{1}{d}$
	$\frac{z_{21}}{z_{11}}$	$\frac{\Delta_z}{z_{11}}$	$-\frac{y_{21}}{y_{22}}$	$\frac{1}{y_{22}}$	$-\frac{h_{21}}{\Delta_h}$	$\frac{h_{11}}{\Delta_h}$	g_{21}	g_{22}	$\frac{1}{A}$	$\frac{B}{A}$	$\frac{\Delta_t}{d}$	$-\frac{b}{d}$
T	$\frac{z_{11}}{z_{21}}$	$\frac{\Delta_z}{z_{21}}$	$-\frac{y_{22}}{y_{21}}$	$-\frac{1}{y_{21}}$	$-\frac{\Delta_h}{h_{21}}$	$-\frac{h_{11}}{h_{21}}$	$\frac{1}{g_{21}}$	$\frac{g_{22}}{g_{21}}$	A	B	$\frac{d}{\Delta_t}$	$\frac{b}{\Delta_t}$
	$\frac{1}{z_{21}}$	$\frac{z_{22}}{z_{21}}$	$-\frac{\Delta_y}{y_{21}}$	$-\frac{y_{11}}{y_{21}}$	$-\frac{h_{22}}{h_{21}}$	$-\frac{1}{h_{21}}$	$\frac{g_{11}}{g_{21}}$	$\frac{\Delta_g}{g_{21}}$	C	D	$\frac{c}{\Delta_t}$	$\frac{a}{\Delta_t}$
t	$\frac{z_{22}}{z_{12}}$	$\frac{\Delta_z}{z_{12}}$	$-\frac{y_{11}}{y_{12}}$	$-\frac{1}{y_{12}}$	$\frac{1}{h_{12}}$	$\frac{h_{11}}{h_{12}}$	$-\frac{\Delta_g}{g_{12}}$	$-\frac{g_{22}}{g_{12}}$	$\frac{D}{\Delta_T}$	$\frac{B}{\Delta_T}$	a	b
	$\frac{1}{z_{12}}$	$\frac{z_{11}}{z_{12}}$	$-\frac{\Delta_y}{y_{12}}$	$-\frac{y_{22}}{y_{12}}$	$\frac{h_{22}}{h_{12}}$	$\frac{\Delta_h}{h_{12}}$	$-\frac{g_{11}}{g_{12}}$	$-\frac{1}{g_{12}}$	$\frac{C}{\Delta_T}$	$\frac{A}{\Delta_T}$	c	d

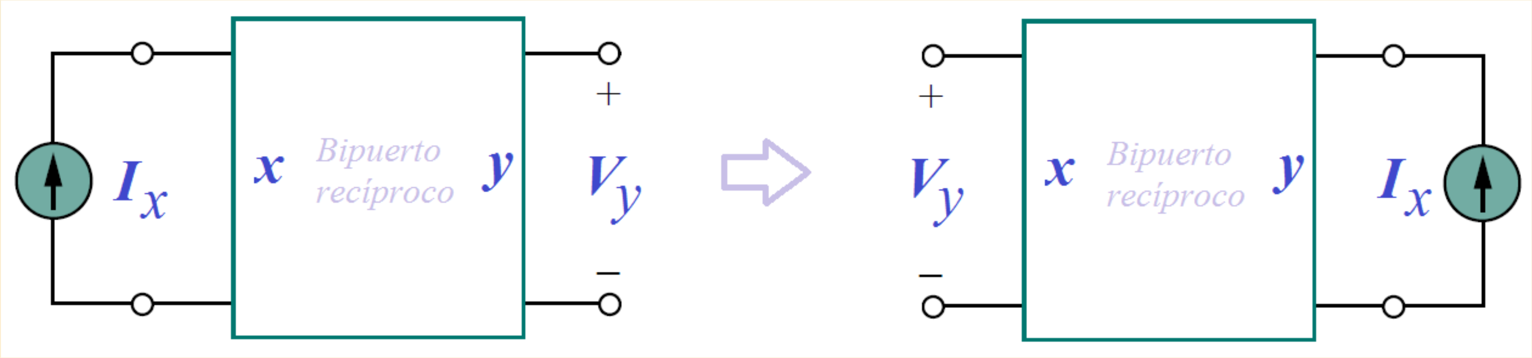
$\Delta_z = z_{11}z_{22} - z_{12}z_{21}$, $\Delta_h = h_{11}h_{22} - h_{12}h_{21}$, $\Delta_T = AD - BC$

$\Delta_y = y_{11}y_{22} - y_{12}y_{21}$, $\Delta_g = g_{11}g_{22} - g_{12}g_{21}$, $\Delta_t = ad - bc$

Teorema de Reciprocidad:

En cualquier red de dos puertos recíproca, si la única fuente de tensión Vx en la rama “x” produce una respuesta de corriente Iy en la rama “y”, entonces, al intercambiar la fuente de tensión de la rama “x” y colocarla en la rama “y”, producirá la misma respuesta de corriente Iy pero en la rama “x”





Reciporcidad:

Una red bipuertos es recíproca si cumple las siguientes condiciones:

a) $Z_{12} = Z_{21}$

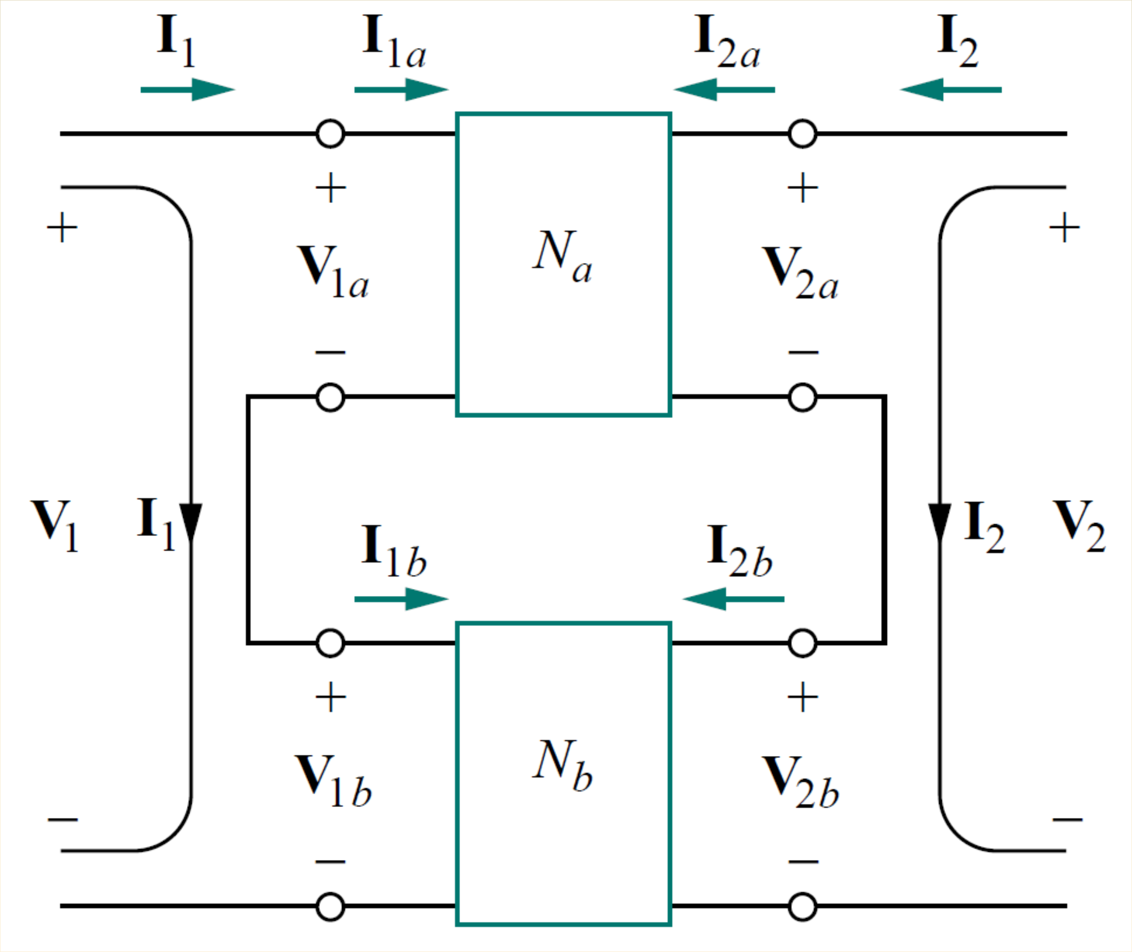
b) $Y_{12} = Y_{21}$

c) $h_{12} = -h_{21}$

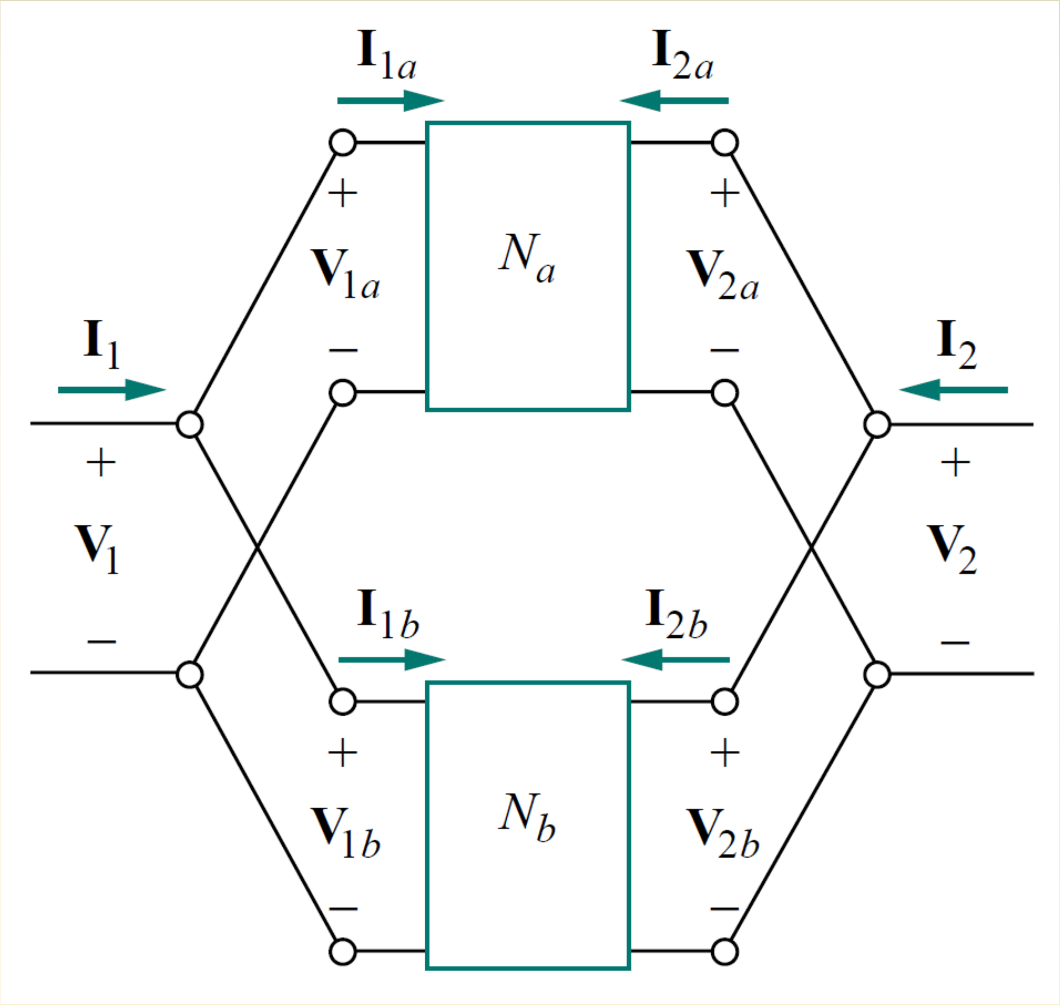
d) $AD - BC = 1$

Cuando $Z_{11} = Z_{22}$ la red se considera simétrica: 2 mitades similares.

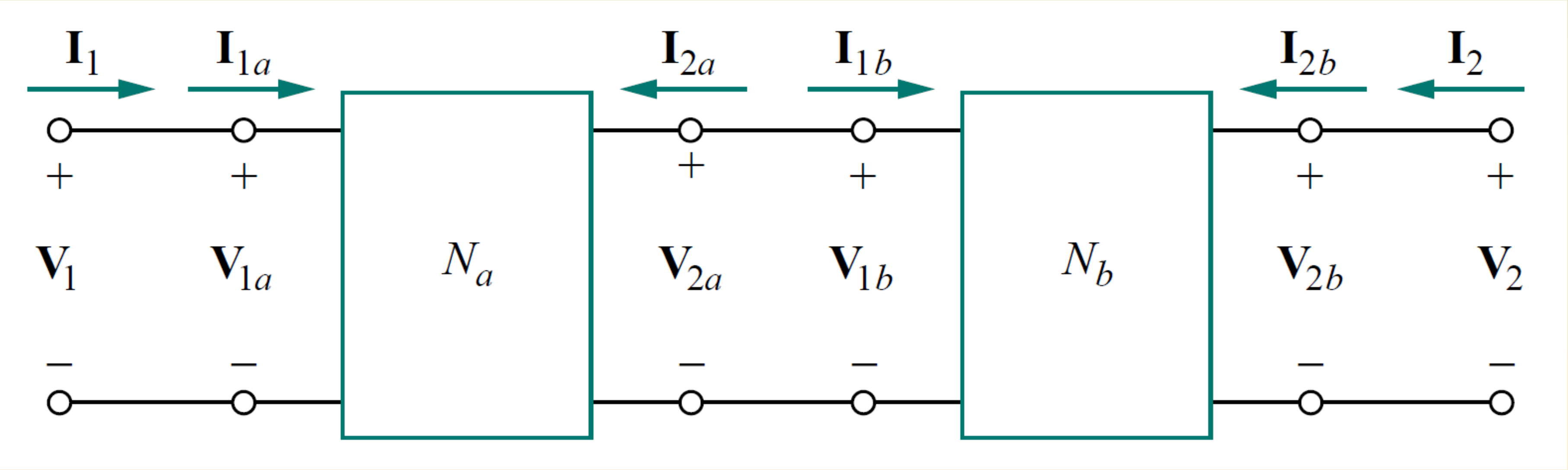
Interconexión de Bipuertos:
Arreglo Serie:



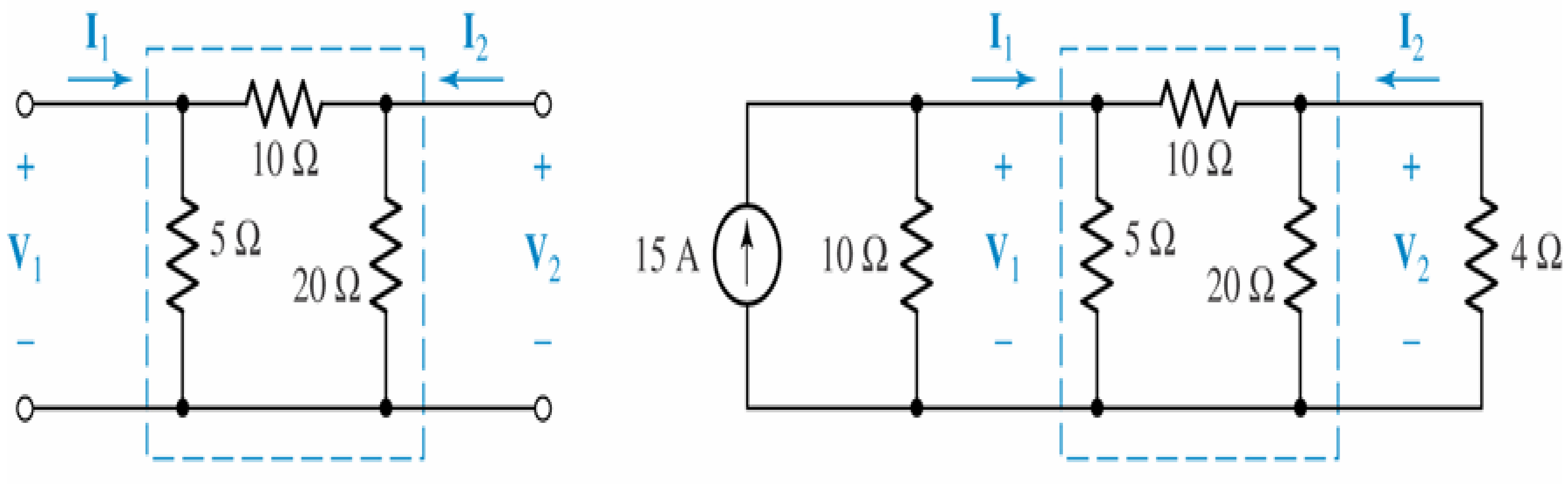
Interconexión de Bipuertos:
Arreglo Paralelo:



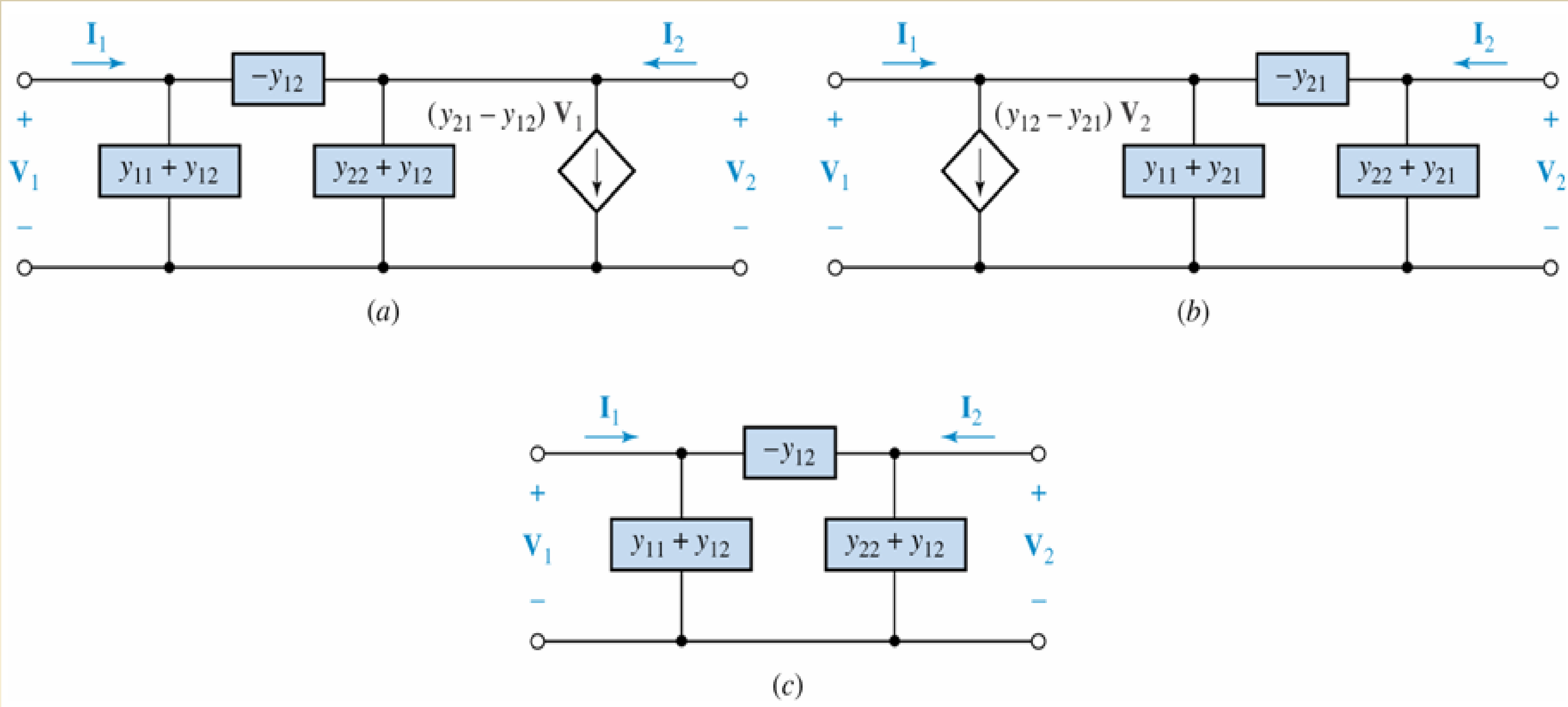
Interconexión de Bipuertos:
Arreglo en Cascada:



Ex.: Find the four short-circuit admittance parameters for the resistive two-port shown below in (a).



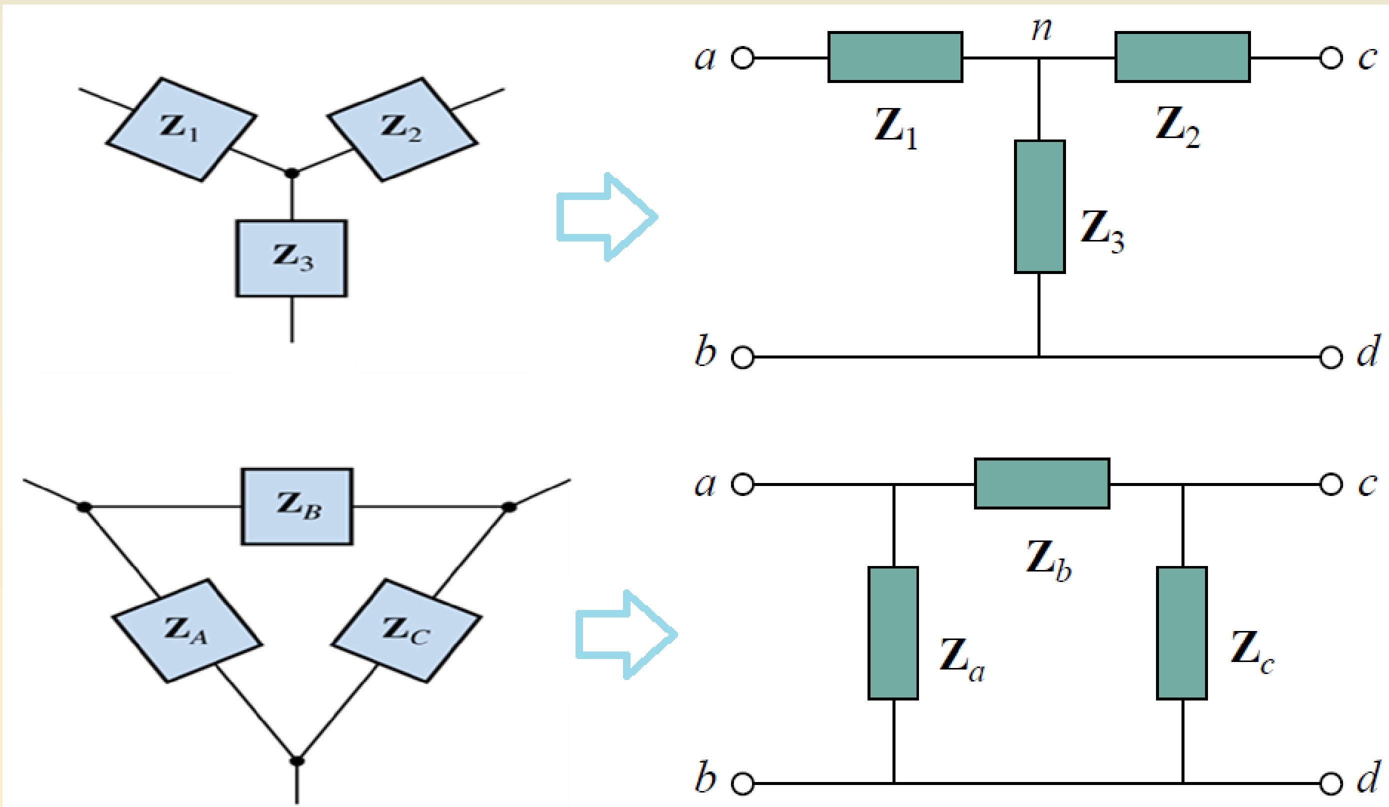
(a) (b)



(*a*, *b*) Two-ports which are equivalent to any general linear two-port. The dependent source in part *a* depends on $\mathbf{V}_1$, and that in part *b* depends on $\mathbf{V}_2$. (c) An equivalent for a bilateral network.

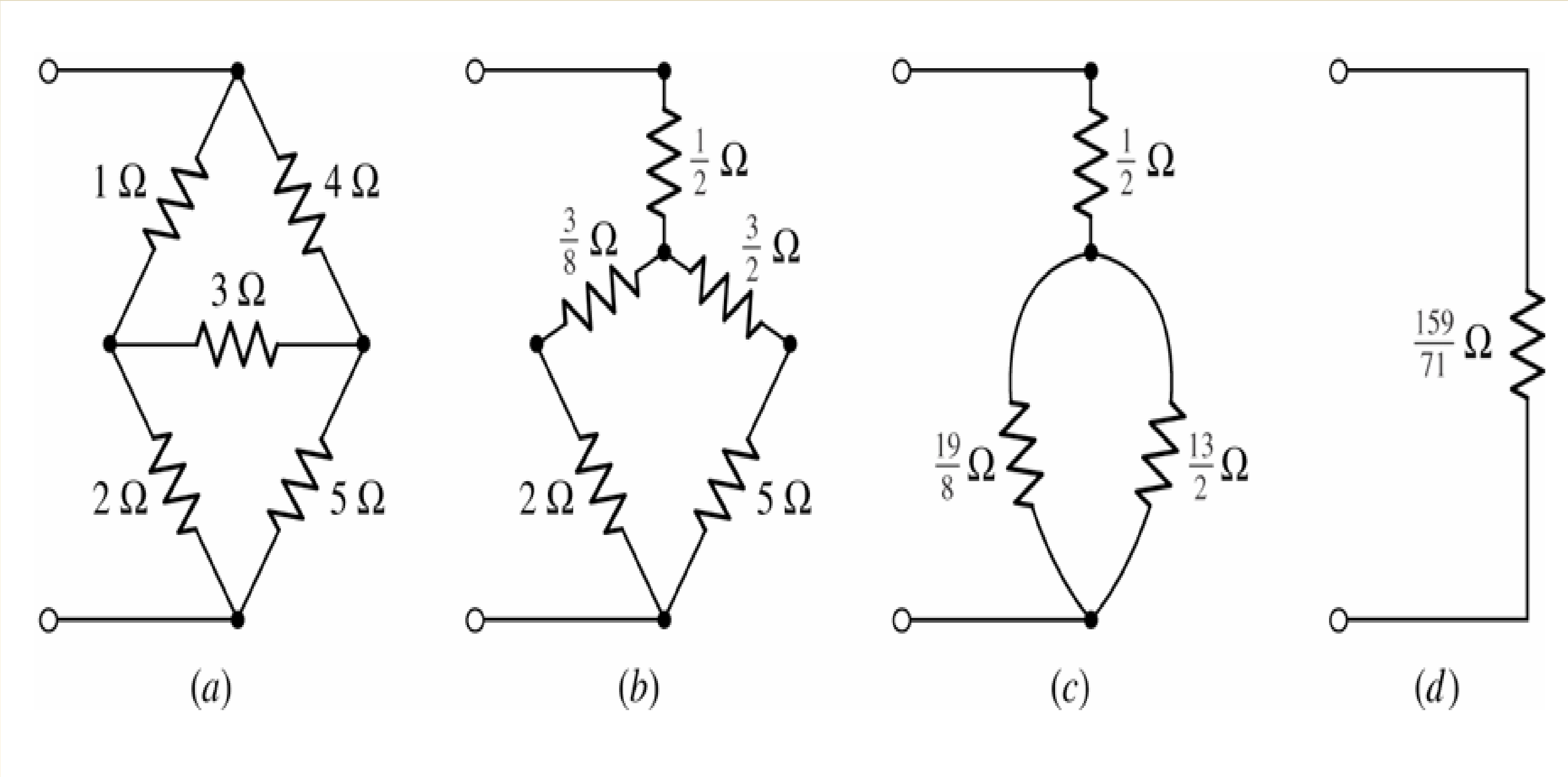
W.H. Hayt, Jr., J.E. Kemmerly, S.M. Durbin, Engineering Circuit Analysis, Sixth Edition.

The three-terminal Δ network (a) and the three-terminal Y network (b) are equivalent if the six impedances satisfy the conditions of the Y-Δ transformation.



W.H. Hayt, Jr., J.E. Kemmerly, S.M. Durbin, Engineering Circuit Analysis, Sixth Edition.

Find the input resistance of the circuit shown in (a).



W.H. Hayt, Jr., J.E. Kemmerly, S.M. Durbin, Engineering Circuit Analysis, Sixth Edition.

Ejo: Parámetros "**h**" o híbridos:

TRANSISTOR AMPLIFIER

Figure 17.9-1 shows the small signal equivalent circuit of a transistor amplifier. The data sheet for the transistor describes the transistor by specifying its h parameters to be

$$h_{ie} = 1250\ \Omega, \quad h_{oe} = 0, \quad h_{fe} = 100, \quad \text{and} \quad h_{re} = 0$$

The value of the resistance R_c must be between 300 Ω and 5000 Ω to ensure that the transistor will be biased correctly. The small signal gain is defined to be

$$A_v = \frac{v_o}{v_{in}}$$

The challenge is to design the amplifier so that

$$A_v = -20$$

(There is no guarantee that these specifications can be satisfied. Part of the problem is to decide whether it is possible to design this amplifier so that $A_v = -20$.)

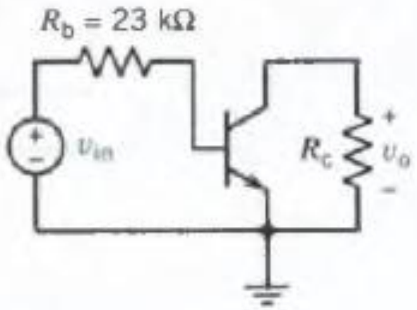


FIGURE 17.9-1 A transistor amplifier.

Describe the Situation and the Assumptions

1. R_c must be between 300 Ω and 5000 Ω.

2. The transistor is represented by h parameters. Figure 17.9-1*a* shows that the transistor can be configured to be a two-port network and represented by h parameters. Figure 17.9-2*b* shows an equivalent circuit for the transistor. This equivalent circuit is based on the h parameters. For this particular transistor, the values of the h parameters are

$$h_{ie} = 1000\ \Omega, \quad h_{oe} = 0, \quad h_{fe} = 100, \quad \text{and} \quad h_{re} = 0$$

Because

$$\frac{1}{h_{oe}} = \infty$$

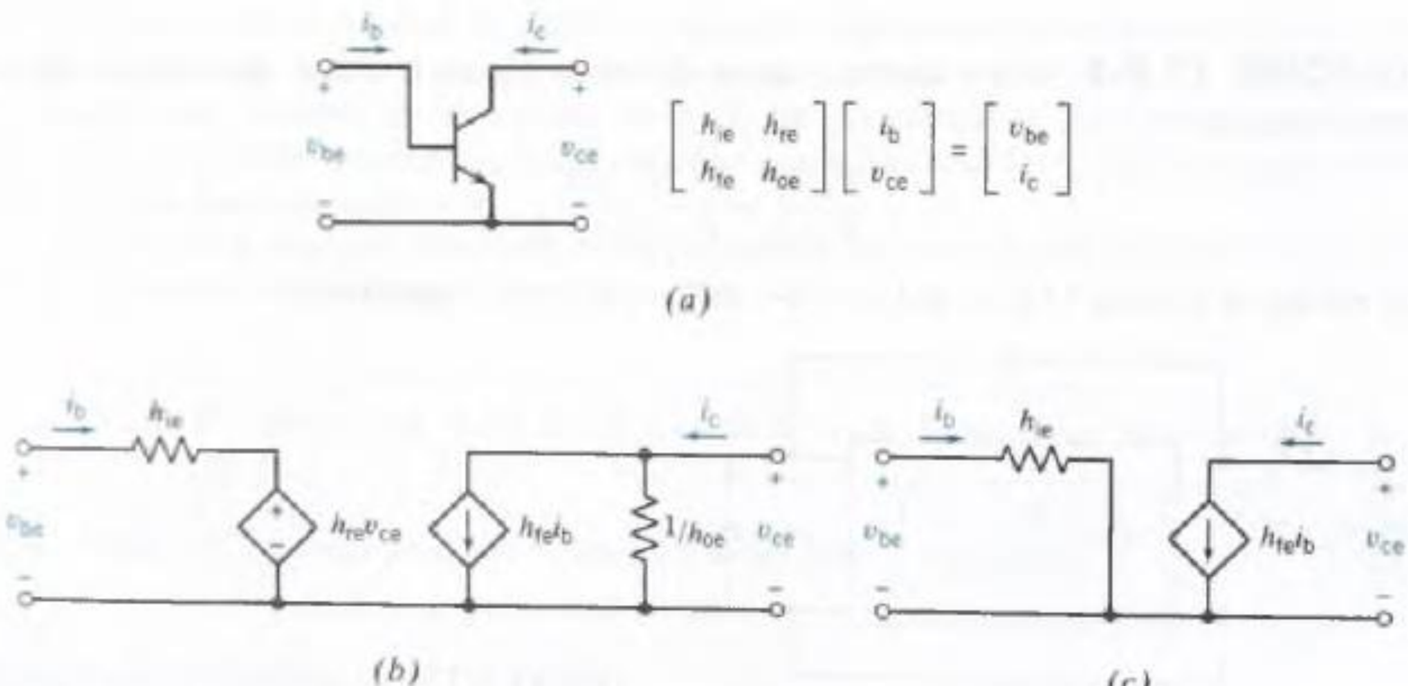


FIGURE 17.9-2 (*a*) Using h parameters to describe a transistor. (*b*) An equivalent circuit. (*c*) A simplified equivalent circuit for $h_{re} = 0$ and $h_{oe} = 0$.

the resistor at the right side of the equivalent circuit is an open circuit. Because

$$h_{re} = 0$$

the dependent voltage source is a short circuit. Figure 17.9-2*c* shows the equivalent circuit after these simplifications are made.

3. The voltage gain must be $A_v = -20$.

State the Goal

Select R_c so that $A_v = -20$.

Generate a Plan

Replace the transistor in Figure 17.9.1 by the equivalent circuit in Figure 17.9-2*c*. Analyze the resulting circuit to obtain a formula for the voltage gain, A_v. This formula will involve R_c. Determine the value of R_c that will make $A_v = -20$. If this value of R_c is between 300 Ω and 5000 Ω, the amplifier design is complete. On the other hand, if this value of R_c is not between 300 Ω and 5000 Ω, the specifications cannot be satisfied.

Act on the Plan

Figure 17.9-3 shows the amplifier after the transistor has been replaced by the equivalent circuit. Applying Ohm's law to R_c gives

$$v_o = -R_c 100 i_b$$

where the minus sign is due to reference directions. Next, apply KVL to the left mesh to get

$$v_{in} = 23{,}000 i_b + 1000 i_b$$

Then

$$A_v = \frac{v_o}{v_{in}} = \frac{-100R_c}{24{,}000}$$

Finally, set $A_v = -20$, obtaining

$$-20 = \frac{-100R_c}{24{,}000}$$

Now solve for R_c to determine

$$R_c = 4800\ \Omega$$

Verify the Proposed Solution

First, the resistance $R_c = 4800\ \Omega$ is indeed between $300\ \Omega$ and $5000\ \Omega$. Second, the gain of the circuit shown in Figure 17.9-3 is

$$\frac{v_o}{v_{in}} = \frac{-h_{fe}R_c}{R_b + h_{ie}} = -\frac{100 \times 4800}{23{,}000 + 1000} = -20$$

Therefore, both specifications have been satisfied.

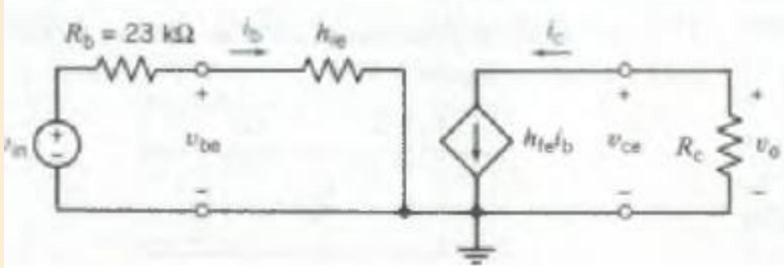
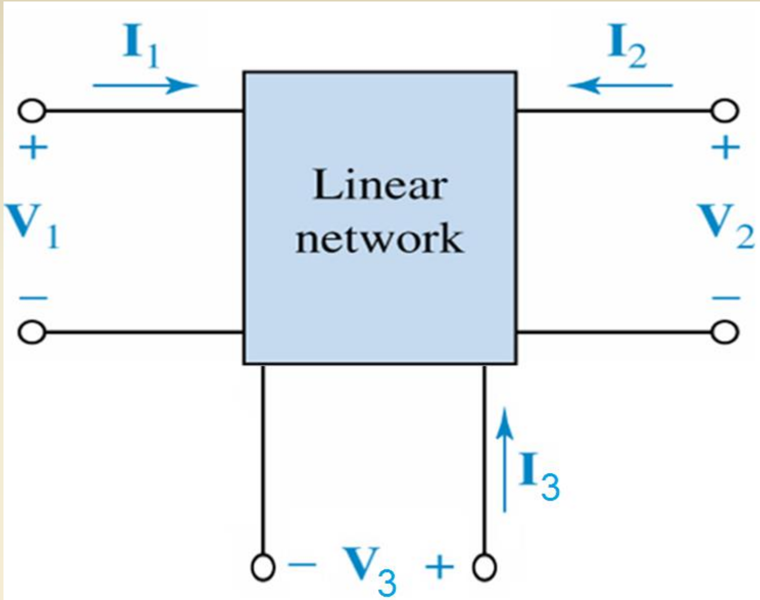
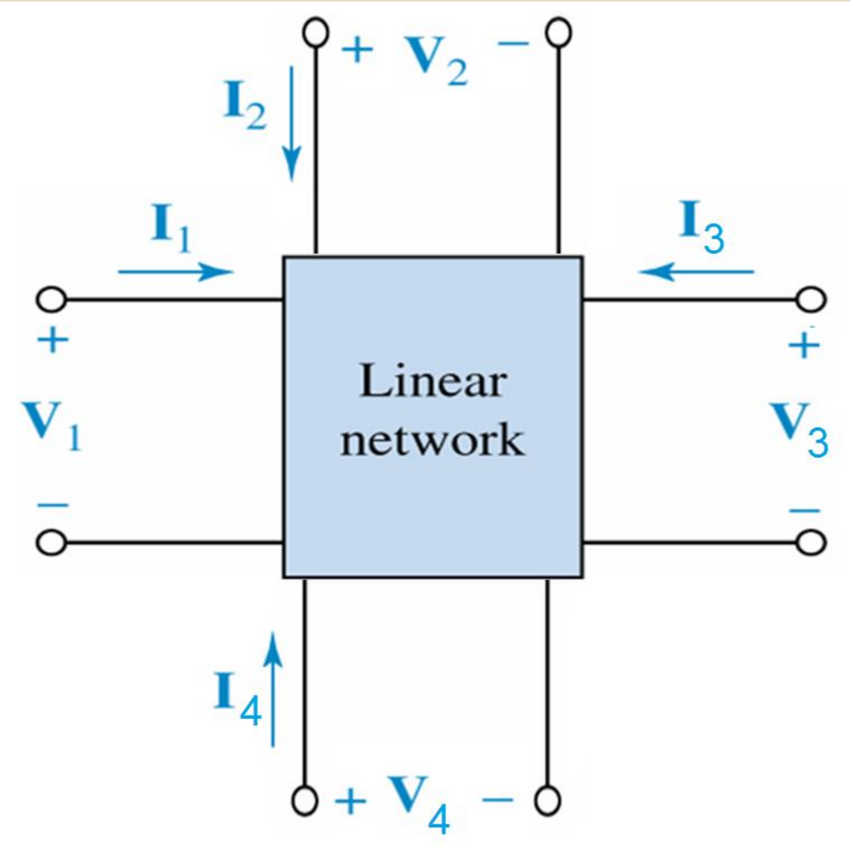


FIGURE 17.9-3 An equivalent circuit for the transistor amplifier.

Tarea: Resolver para redes Tripuertos y Cuadripuertos





$$\begin{bmatrix} Q_1 \\ Q_2 \\ .. \\ Q_n \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} & \dots & K_{1n} \\ K_{21} & K_{22} & \dots & K_{2n} \\ .. & .. & \dots & .. \\ K_{n1} & K_{n1} & \dots & K_{nn} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ .. \\ P_n \end{bmatrix}$$